THE 1995 HAWAIIAN INTERNATIONAL BILLFISH TOURNAMENT: AN OCEANOGRAPHIC PERSPECTIVE

by

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INTRODUCTION

Ocean activity has long been recognized to play a key role in the distribution, migration, availability, and catchability of pelagic fishes such as billfishes.[1] Ocean fronts and eddies in particular have been shown to attract and sustain these large, rapidly swimming animals.[2] In Hawaiian waters, the combination of prevailing northeasterly tradewinds and island topography encourages the generation of vigorous eddies or current swirls on the leeward side of the islands creating the potential for very productive fishing areas. These physical features are nowhere more conspicuous and occur more frequently than off the Kona coast of the Big Island, site of Hawaiian International Billfish Tournament (HIBT).[3]

During the 1995 HIBT, the National Marine Fisheries Service (NMFS) conducted a research cruise off the southwest Kona coast of Hawaii, with primary objectives of mapping the prevailing oceanographic features and determining if and to what degree these conditions influenced tournament billfish catches. The oceanographic data were collected aboard the National Oceanic and Atmospheric Administration (NOAA) ship *Townsend Cromwell* over an area about 50 nautical miles (nmi) longitude by 60 nmi latitude. The sampled region extended well beyond the limits of the tournament fishing activity (Fig. 1a) but nevertheless proved critical in providing insight into intermediate scale (e.g. tens to hundreds of miles) oceanographic features, such as the eddies mentioned above. Information on current speed and direction and water temperature and salinity were compared to the daily catch record for the HIBT provided by the Pacific Ocean Research Foundation (PORF) to evaluate the relationship between the oceanography and billfish catchability. The results are presented here.

THE OCEANOGRAPHY

During tournament week, ocean conditions off the leeward coast of Hawaii were dominated by the presence of a counterclockwise rotating current or eddy field. The eddy, centered about 20 nmi off Kailua-Kona and occupying a region of about 60 nmi in diameter, is schematically represented in Figure 1b.

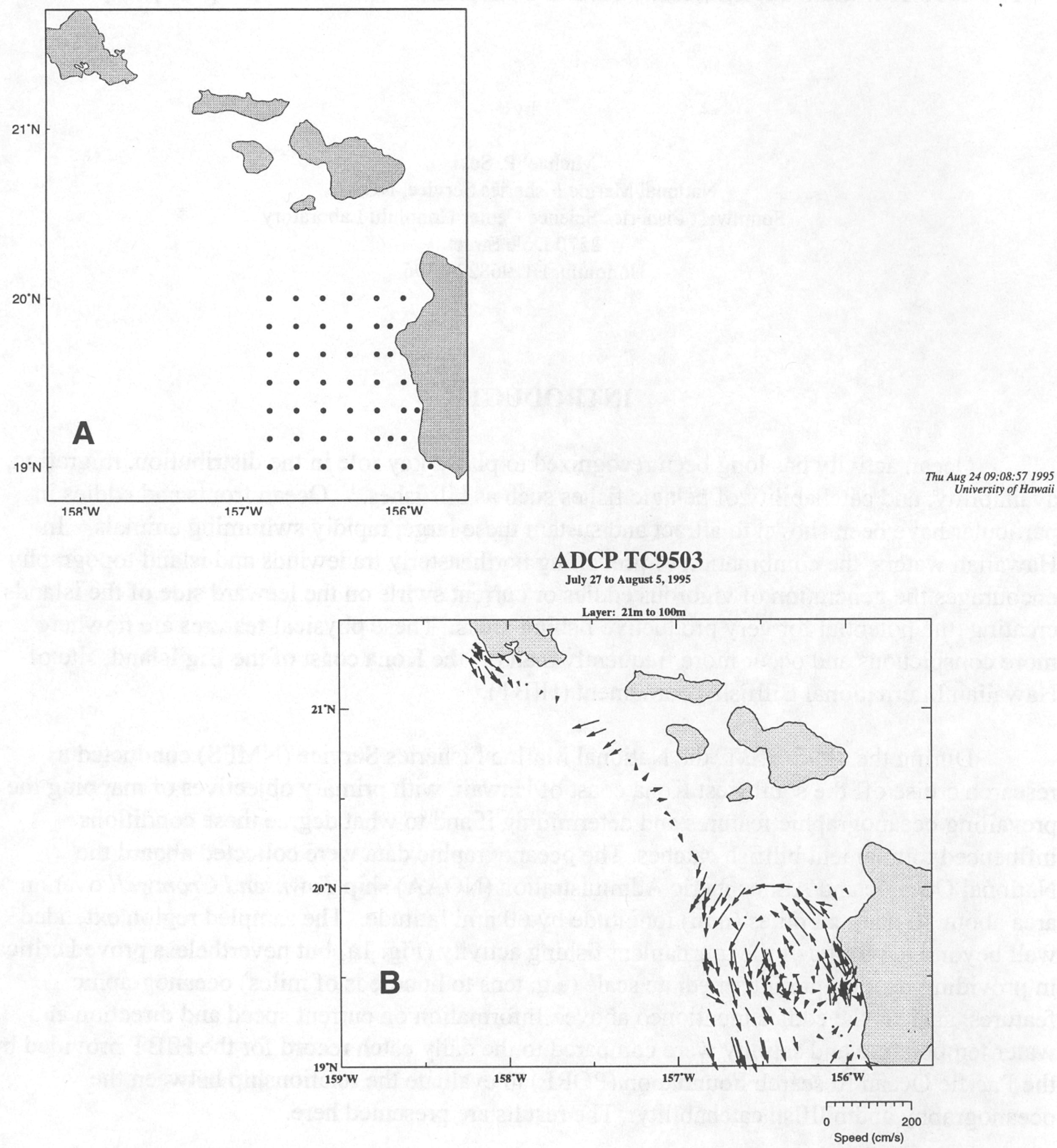

Figure 1. (A) Oceanographic station sampling grid and (B) schematic vector representation of estimated current velocities and direction along the cruise track of the *Townsend Cromwell* (TC), 26 July - 5 August 1995. The vectors (arrows) have lengths scales to reflect relative current speeds and point in the direction of the current flow. Measurements were averaged over the upper 11-55 fathoms (21-100 m).

As indicated above, the occurrence of oceanic eddies of this scale is not uncommon for waters adjacent to the Big Island lee.[3] When present, these eddies will dominate all other coastal currents often creating extended periods of strong unidirectional coastwise flow.[4] Within the fishing grounds (i.e., the 20 nmi closest to shore) the eddy generally appeared as a strong north-northwest current running up the coast towards Keahole Point, where the flow turned west offshore essentially following the island topography.

As an example to show how current velocities and direction are distributed throughout the eddy field, vertical sections of the water-column are presented in Figure 2 for the region off Captain Cook (along the 19°30'N latitude) and in Figure 3 for the region off Kailua-Kona (along 19°40'N latitude). Vertical sections such as these are typically used to show the depth distribution of physical properties and in the case of currents, are presented as east-west and north-south directional components of the total current structure. When viewing the figures, note that the annotated current velocities are expressed in units of cm/sec where 1 cm/sec ≅ 0.02 knots (or 1 knot ≅ 50 cm/sec) and that all longitudes are expressed in decimal degrees (e.g. 156.5°W = 156°30'W). Shaded contours in the figures correspond to the portion of the currents directed to the west and to the north in their respective plots and the unshaded areas to the portion of the currents directed to the east and south. For example, the strong north-northwest flow just off the coast can be deduced from the high valued, unshaded (white) northbound regions in Figures 2b and 3b and the shaded (grey) westbound regions in Figures 2a and 3a. Generally, current velocities were strongest in the upper 250 ft (75 m) of the surface, where measured speeds exceeded 1.2 knots (60 cm/sec) towards the outer edge (periphery) of the eddy field. These current speeds diminished rapidly (approaching zero horizontal velocity) towards the eddy center (interior). In deeper waters, current speeds in the main eddy flow measured about 0.78 knots (40 cm/sec). An interesting perspective would be to note that at these rates, something carried along in the eddy flow would complete one revolution around the gyre in about 6.5 days (157 h).

Deep surface mixed layers at the periphery and a shallow front towards the interior further characterized the eddy field. These features can be visualized in diagrams depicting the distribution of water properties. For example, Figure 4 illustrates how temperature and salinity varied with depth through the eddy for the same vertical sections in the previous figures (i.e., along the 19°30' and 19°40 N latitudes). Note the presence of the well-defined surface layer in both channel waters far offshore and in nearshore waters on the tournament grounds. This is the homogeneous, uniform water observed from the sea surface to the top of the thermocline (the region where temperature changes rapidly with depth) at about 230 ft (70 m). In contrast, the water column of the eddy interior is well stratified, with properties changing gradually and continuously with depth and no evidence of mixing. Regions characterized by well-defined surface layers thus coincided with the areas of strongest current velocities, i.e., the eddy periphery. Since mixed layers normally tend to be the product of wind-generated turbulence, the existence of the inshore surface layers here off Kona in the absence of much wind stress is probably ascribed directly to the eddy energy. It follows then that the water mass present in the tournament region was likely composed largely of recirculated or well-mixed water advected or carried in from offshore. The difference in the environment at the periphery of the eddy as compared to that found in the interior further leads to a rapid change or gradient in properties (currents speed, temperature, etc.) between the two locales with most adjustment occurring over

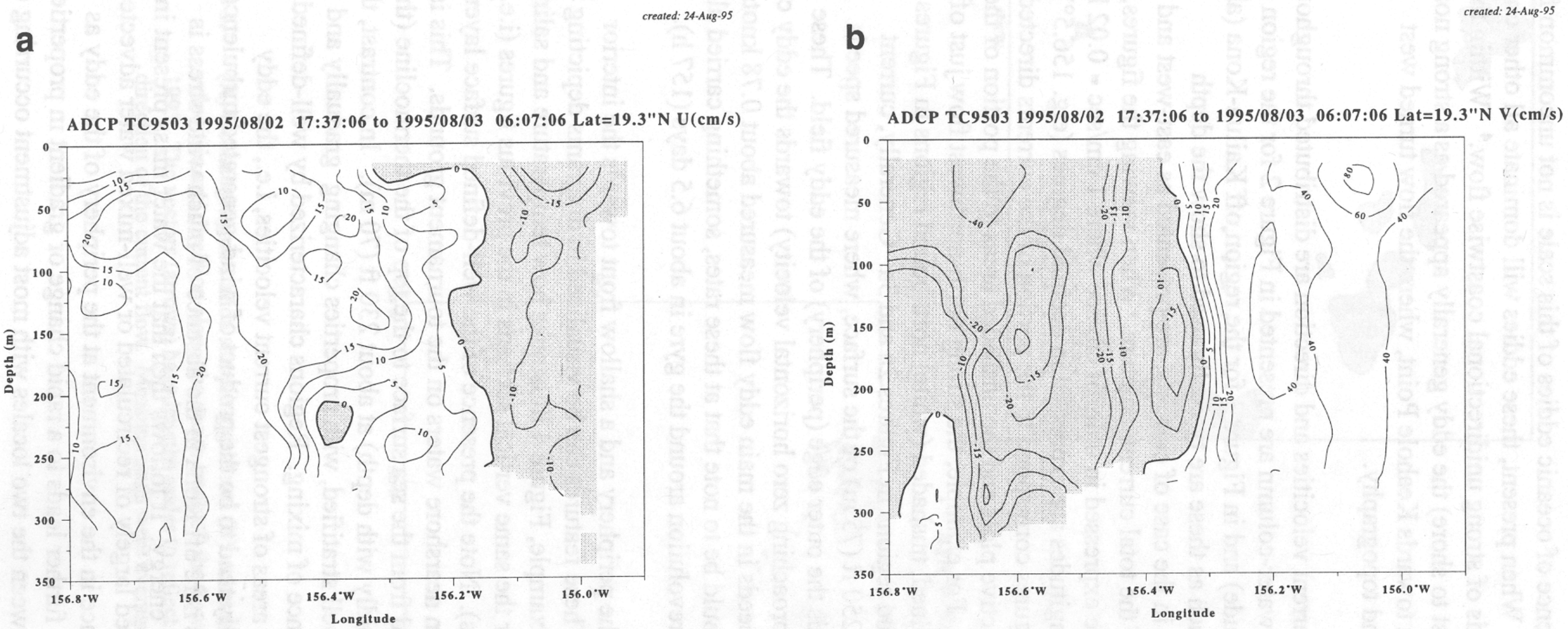

Figure 2. Vertical profiles of depth-averaged estimated current velocities off Captain Cook; i.e., along 19°30'N latitude and between ca. 156°00'W and 156°50'W longitudes, 1737 h, 2 August 1995 - 0607 h, 2 August 1995 (GMT), *TC* 95-03: (a) east-west velocity component "**u**" (cm/s) and (b) north-south velocity component "**v**" (cm/s). White areas represent net eastward and northward flow in (a) and (b), respectively; shaded areas represent net westward and southward flow in (a) and (b), respectively.

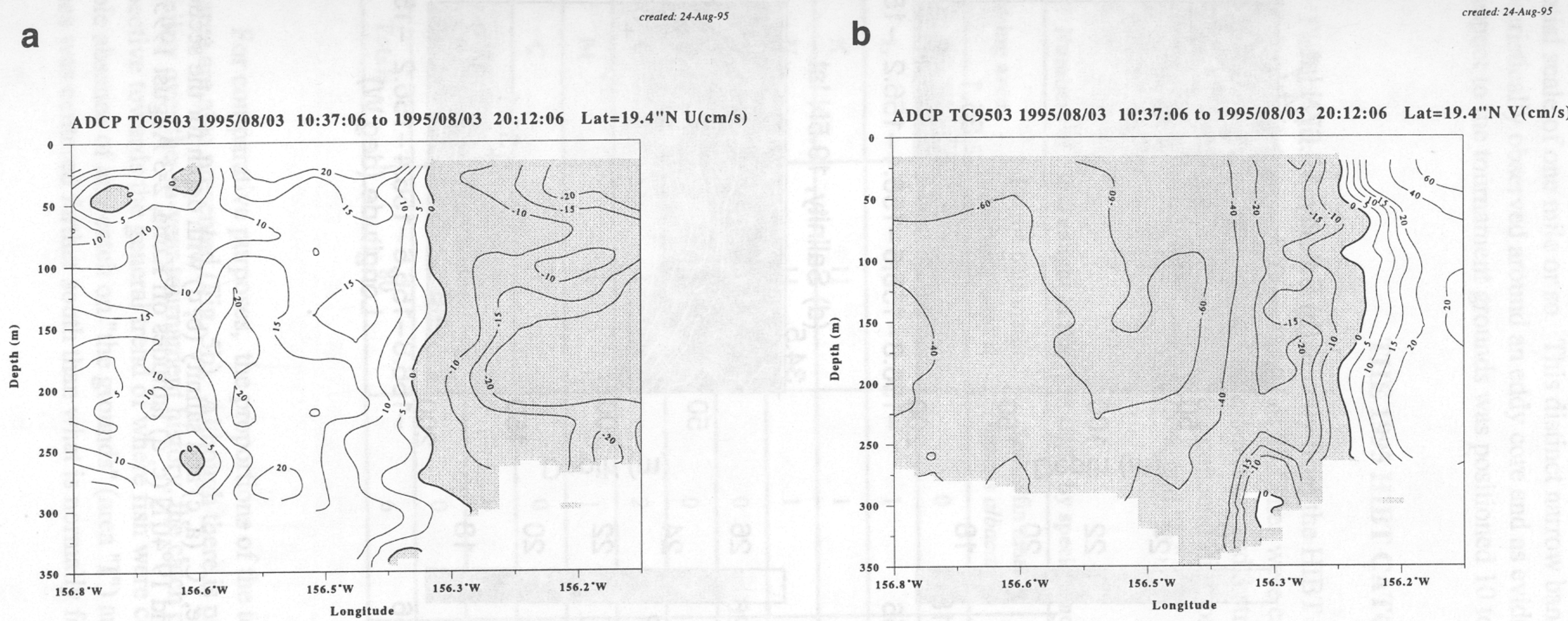

Figure 3. Vertical profiles of depth-averaged estimated current velocities off Kailua-Kona; i.e., along 19°40'N latitude and between ca. 156°10'W and 156°50'W longitudes, 3 August 1995, TC 95-03: (a) east-west velocity component "**u**" (cm/s) and (b) north-south velocity component "**v**" (cm/s). White areas represent net eastward and northward flow in (a) and (b), respectively; shaded areas represent net westward and southward flow in (a) and (b), respectively.

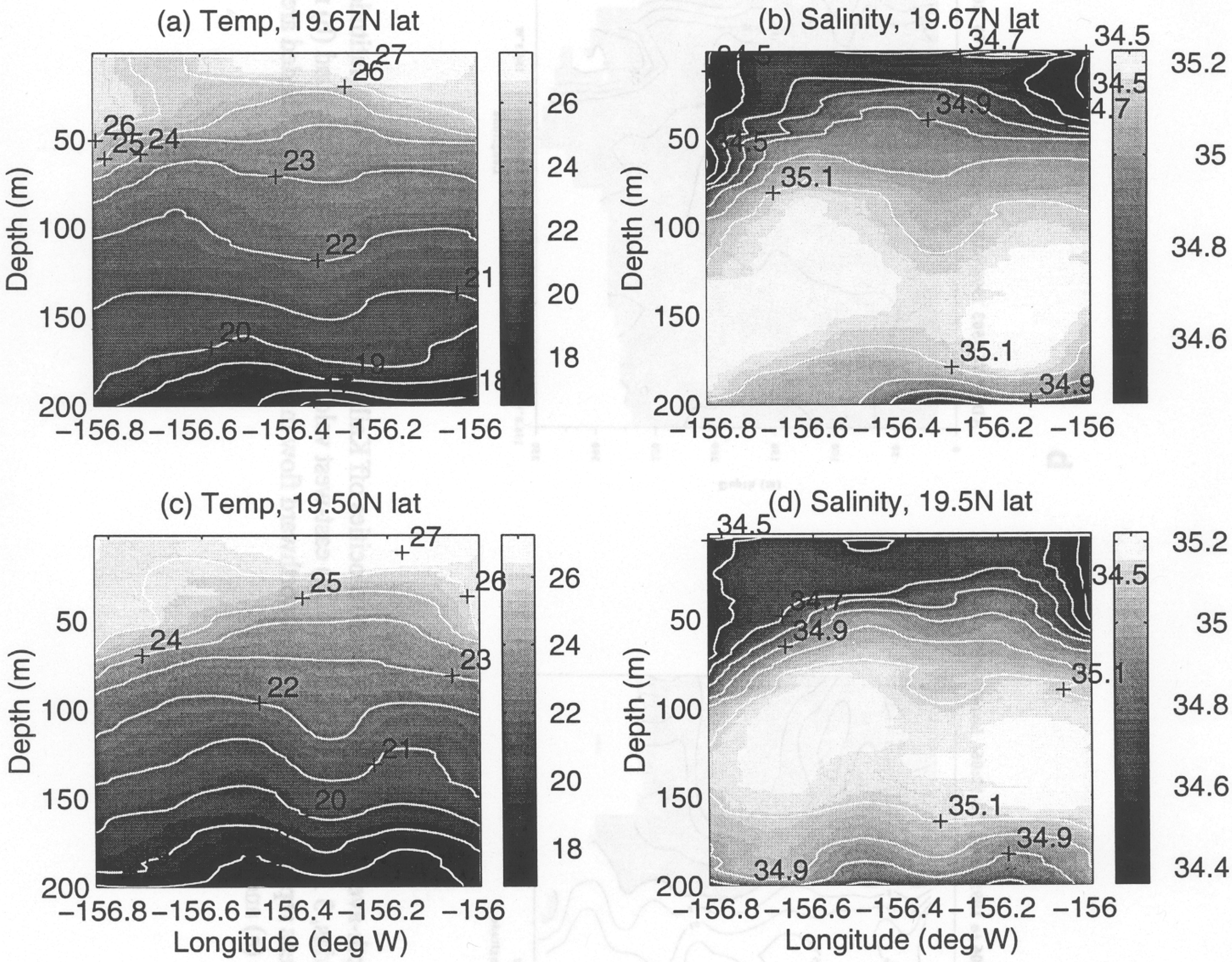

Figure 4. Distribution of temperature, °C, (a, c) and salinity (b, d) with depth for the sections along the 19°30'N (a, b) and 19°40'N (c, d) latitudes off Kona, 2-3 August 1995.

the spatial scale of one mile or so. This distinct narrow band defines the front that is characteristically observed around an eddy core and as evidenced in Figures 2, 3 and 4, the front with respect to the tournament grounds was positioned 10 to 12 nmi offshore.

THE 1995 HIBT CATCH

Fish catches were extracted directly from the HIBT daily catch record for the tournament week 31 July to 4 August 1995. A total of 89 fishes were caught: 80 Pacific blue marlin, *Makaira mazara*, 6 yellowfin, *Thunnus albacares*, and 3 striped marlin, *Tetrapturus audax* (Table 1). For blue marlin specifically, the concentration of catches occurred in areal blocks "S" where 20.0% were landed, "L" with 18.75%, and "K", "T" and "U" each with 13.75% of the total marlin catch (Fig. 5a).

Table 1. Numbers of fishes caught in the 1995 HIBT by species and area.

Fishing area	Pacific blue marlin, *Makaira mazara*	Yellowfin tuna, *Thunnus albacares*	Striped marlin, *Tetrapturus audax*	**Totals**
S	16	0	1	17
L	15	1	0	16
K	11	1	1	13
U	11	1	0	12
T	11	0	0	11
J	6	0	0	6
V	4	2	0	6
M	3	1	0	4
C	1	0	1	2
B	1	0	0	1
D	1	0	0	1
Totals	80	6	3	89

For comparative purposes, the proportions of the total historical blue marlin catch for each area are also presented (Fig. 5b). Although there is probably considerable interannual variability over the 36-year tournament history, the catch per area of pooled data provides a good perspective towards the general trend of where fish were caught. As for 1995, there was a notable absence of any catch on "the grounds" (area "I") and generally, the concentration of catches was centered farther south than what is normally found.

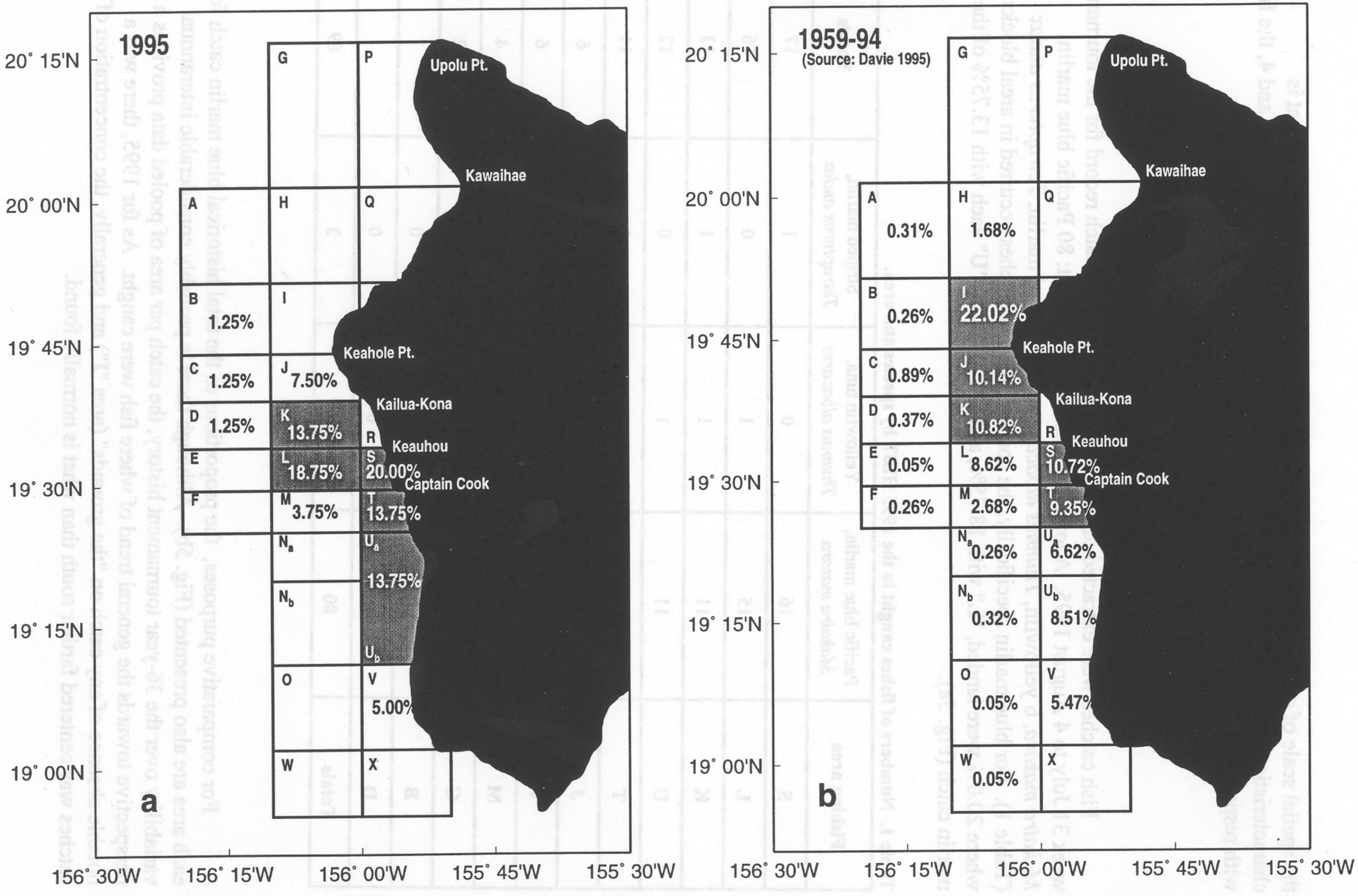

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Figure 5. HIBT blue marlin catches (% of total number) for (a) 1995 and (b) 1939-1994[5].

AN ECOSYSTEM ASSESSMENT

Areas of highest blue marlin catches coincided with (1) regions over which the strongest fronts and surface gradients of temperature, salinity, etc. were observed ("**L**" and "**K**") and (2) regions of strong coastwise current and deep surface mixed layers ("**S**", "**T**", and "**U**") (Fig. 6).

Some insight into the basis behind the development of these patterns may be gained from our existing understanding of blue marlin biology and ecology. For example, acoustic tracking studies conducted off Kona have shown blue marlin to exhibit a marked preference for the warm surface mixed layer above the thermocline and particularly where water temperature varied between 26° and 27°C (78.8°- 80.6°F).[6,7] More importantly, while blue marlin are capable of ranging through the thermocline, they apparently rarely do so.[7] This would suggest that blue marlin migrating into waters south of Keahole Point during the tournament would have been compelled to confine their movements within the narrow swath between the coastline and the front interfacing the stratified eddy interior to remain in their preferred habitat. By limiting their horizontal movement between these bounds (essentially restricting their movement to the peripheral eddy flow), the catchability of the marlin likely increases.

The interplay between the ocean conditions and blue marlin foraging may prove an integral link to observed catch patterns. The physical environment may provide cues for marlin to locate prey or more directly, may aggregate or concentrate food items. Movements and distribution of small tunas, which diet studies have shown to be a particularly favored food among blue marlin,[8,9] can be strongly influenced by fronts and prevailing ocean conditions.[10,11] Additionally, peculiar to the diet of blue marlin captured in coastal waters off Kona was the prevalence of larval and juvenile reef fishes.[9] Since these fishes may be transported, carried along, or aggregated by local eddies and currents,[12] an eddy field such as that observed in 1995, could create a unique feeding environment that would make these prey readily available.

Attempts to decipher catch patterns with respect to the environment also need to consider the role of reproductive strategy in dictating blue marlin movement and distribution. Summer influx of blue marlin onto the fishing grounds appears directly tied to seasonal spawning migrations.[13] Conceivably, blue marlin spawning cues may have evolved to target oceanographic features, such as eddies, that are commonly found here during this time of year. Eddies when present, could mechanically limit dispersal of young marlin,[2,12] thereby helping to retain them within waters favorable to their growth and survival. Interestingly during the survey, nine blue marlin larvae[14] were caught in a mere five surface plankton tows made within 20 nmi of the shore; none were taken in seven tows made 50 nmi out.

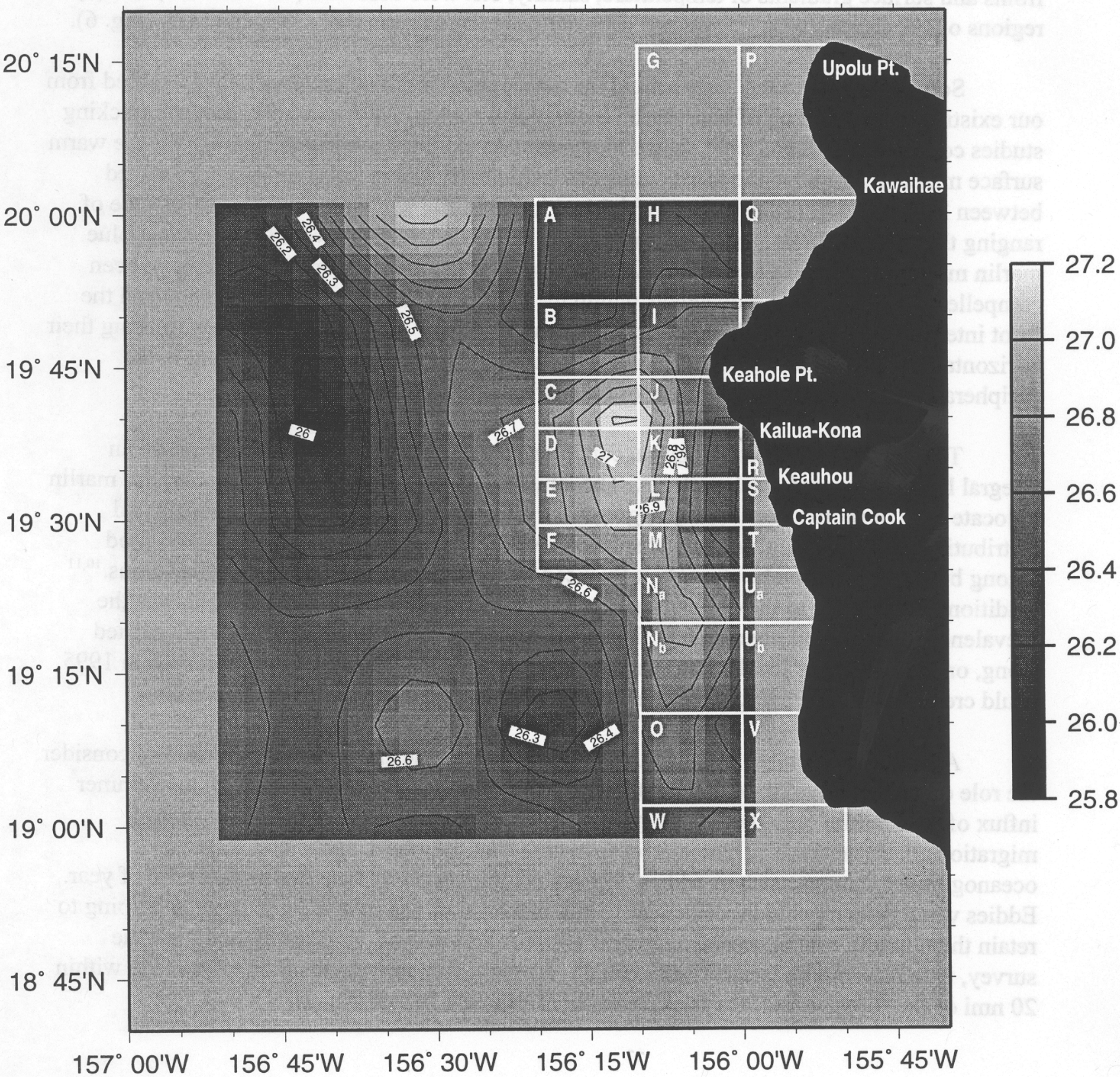

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Figure 6. Sea surface temperatures during the 1995 HIBT

SUMMARY

A counterclockwise rotating eddy physically occupying some 2,500 square miles of surface area dominated the oceanography off the Kona coast of Hawaii during the 1995 HIBT. On the tournament grounds, well-mixed surface layers and strong current flows characterized inshore waters surveyed south of Keahole Point. Offshore, localized fronts formed at the interface of the eddy periphery and core. Areas of high tournament fish catches coincided with these ocean features, suggesting direct (e.g. physiological limitations) and/or indirect (e.g. prey availability) biological responses of blue marlin to the environment. All considered, there was compelling evidence supporting the notion that the prevailing ocean conditions was the principle factor influencing fish availability during the 1995 HIBT.

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[14]equivocal diagnostic characters keep the larvae identification to blue marlin tentative; IDs courtesy of Bruce C. Mundy.

FIGURE LEGENDS

Figure 1. (a) Oceanographic station sampling grid and (b) schematic vector representation of estimated current velocities and direction along the cruise track of the *Townsend Cromwell* (TC), 26 July - 5 August 1995. The vectors (arrows) have lengths scales to reflect relative current speeds and point in the direction of the current flow. Measurements were averaged over the upper 11-55 fathoms (21-100 m).

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Figure 3. Vertical profiles of depth-averaged estimated current velocities off Kailua-Kona; i.e., along 19°40'N latitude and between ca. 156°00'W and 156°50'W longitudes, 3 August 1995, *TC* 95-03: (a) east-west velocity component "**u**" (cm/s) and (b) north-south velocity component "**v**" (cm/s). White areas represent net eastward and northward flow in (a) and (b), respectively; shaded areas represent net westward and southward flow in (a) and (b), respectively. True current direction and velocities are defined by the sum of these components.

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Figure 5. Catch, as proportion of total catch, of Pacific blue marlin by fishing area at the HIBT for (a) 1995 and (b) 1939-1994[5].

Figure 6. Horizontal eddy structure revealed in sea surface temperature (SST) distribution. Map of HIBT fishing areas is overlaid to help illustrate the relationship between fishing and eddy position. The sharp SST gradient (changes) is clearly seen embedded in the eddy frontal zone. These features should also be detected through satellite imagery.